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EFFECT OF N: P: K RATIOS ON GROWTH CHARACTERS, JUICE QUALITY AND PHYSICO-CHEMICAL PROPERTIES OF SUGARCANE

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INTRODUCTION

COMPARATIVE studies on this and other crops showed that good growth took place when the intensity of nutrition and adequate physiological balance among nutrients were maintained in the medium of growth (Tyner, 1947; Lal, Srivastava and Pathak, 1949; Lal and Prasad, 1948; and Lal and Rao, 1952). Adequate balance between nitrogen and phosphorus, in general, resulted in better growth, while greater displacement in NPK equilibrium caused considerable variation in yield (Stanford *et al.*, 1941). A proper association of nitrogen and potassium was also considered helpful for yield (Alov, 1944). Varying ratios of macro-elements were also known to influence production in artificial cultures (McCall and Woodford, 1938). In almost all these cases, fertilizers affected absorption and utilisation of elements and thereby determined growth of plants (Beckenbach *et al.*, 1938; Craige, 1941; and Lundegardh, 1941). An attempt has been made in this paper to explore some of these possibilities, and to suggest the critical limits of added nitrogen, phosphorus and potassium for good growth of sugarcane. Valuable information on sugarcane sap characteristics under these conditions of nutrition have also been provided.

EXPERIMENTATION

The investigations were conducted on sugarcane (var. Co 453) grown in local sandy loam soil in pot cultures. Details of these cultures were as follows:—

Pot size	..	18″×12″.
Quantity of soil	..	25 kg. per pot.
Treatments	..	16 combinations of NPK as follows:

Treatment No.	Conc. in gm. equivalent per culture			Total Conc. in G.E.
	N	P_2O_5	K_2O	
1	15	15	75	105
2	75	15	15	105
3	60	15	30	105
4	45	15	45	105
5	30	15	60	105
6	15	30	60	105
7	30	30	45	105
8	45	30	30	105
9	60	30	15	105
10	15	45	45	105
11	30	45	30	105
12	45	45	15	105
13	15	60	30	105
14	30	60	15	105
15	15	75	15	105
16	0	0	0	(Control)

Each of the above 16 treatments was replicated three times. Single budded setts were sown on 4th March 1951, while transplanting of the germinated setts in pots was done on 20th March 1951. Fertilizers were applied in two equal instalments, half at planting and half 60 days after planting. Nitrogen, phosphorus and potassium were applied as sulphate of ammonia, superphosphate and sulphate of potash respectively.

Barring control, where no fertilizers were added, all other treated cultures were maintained at a total concentration of 105 gm. equivalent of the three nutrients. Within this limit, the ratio of the three ingredients was altered as shown above.

All care was taken to provide adequate irrigation and hoeing at successive stages of the life-cycle. Sampling for growth studies was done at 140 and 190 days, while physico-chemical properties and juice characters were

investigated at 190 and 250 days. The responses depict the effects of additional doses and ratios of nutrients. Bacterial activity was considered to affect all cultures uniformly; differences due to uncontrollable factors were automatically eliminated when the differences between two observed means were compared against the standard differences at 5% level while assessing the validity of the observed effects on growth and physico-chemical properties.

The procedure of recording growth in terms of height, tillering, leaf number and of estimating the physico-chemical properties like density, surface tension, viscosity, osmotic pressure and solute concentration was similar to that indicated in the earlier paper (Lal and Tandon, 1954). Summarized results are represented in text figures. Only the statistically significant effects are recorded in these pages.

Experimental Findings and Discussion

General Effect of Nutritional Ratios, Age and Plant Parts.—Nutrient ratios showed a highly significant effect on leaf number, size of the cane and shoot height. Stage of growth at which samples were taken for these measurements also affected all the growth characters significantly. The effect of various N: P: K ratios was equally significant on total solids and sucrose percentage of cane juice (Table I). All physico-chemical properties

TABLE I

Effect of various combinations of N, P and K on different juice characters

Analysis of Variance

1951–52

Due to	D.F.	Mean sum of squares × 1,000			
		Shoot No.	Leaf No.	Cane Height	Shoot Height
Combinations	15	2500·000	78325·000*	214550·000*	384353·979*
Stages ..	1	36125·000*	470500·000*	11419380·000*	19765052·813*
Error ..	15	971·700	11900·000	84380·000	146200·813
Total ..	31	..	..	..	..

* Significant at 5%

Effect of various combinations of N, P and K on different juice characters

Analysis of Variance

Age 205 days, 1951–52

		Mean sum of squares × 1,000,000		
		Total solids	Sucrose %	Purity %
Combinations	11	9200000·000*	14415420·000*	60225000·000
Samples	1	700·000	1010·000*	163000·000*
Error	11	6600·000	45·000	69000·000
Total ..	23	..	..	..

* Significant at 5%

were significantly affected under various treatments. The effect varied with the parts of the plants sampled for these physico-chemical measurements. This was clearly indicated by the significant effect of interaction between the nutrient ratios and component parts on viscosity, osmotic pressure and solute concentration (Table II).

Growth Characters under Different Ratios.—Shoot number attained highest value under $N_{45}P_{15}K_{45}$ and $N_{15}P_{75}K_{15}$. It was also noted that the number of leaves and shoots declined significantly between the period of 140–190 days. Largest number of leaves was formed under $N_{45}P_{15}K_{45}$. Cane height and total shoot height were significantly improved with advance in age and certain treatment. Thus cane height was the best under $N_{30}P_{30}K_{45}$. Similarly total plant height including green tops was best under $N_{45}P_{30}K_{3}$. Total solids content of the extracted juice was maximum under a ratio of $N_{60}P_{15}K_{30}$. Sucrose percentage also varied from a lower limit of 13·87% under $N_{75}P_{15}K_{15}$ to an upper limit of above 20·0% in $N_{30}P_{15}K_{60}$, $N_{15}P_{30}K_{60}$, $N_{30}P_{30}K_{45}$ and $N_{15}P_{60}K_{30}$. Purity coefficient was also very high (above 90%) under $N_{30}P_{15}K_{60}$, $N_{30}P_{30}K_{45}$, $N_{30}P_{45}K_{30}$, $N_{15}P_{60}K_{30}$ and $N_{30}P_{60}K_{15}$ (Tables III and IV). It thus appeared that in spite of the total concentration of nutrients remaining similar, variations in the relative proportion of the three ingredients resulted in marked differences in growth and juice characters of sugarcane. Only under suitable ratios were the growth and juice characters optimum. For efficient sugarcane production, therefore, the maintenance of such ratios appeared most desirable.

TABLE II

Effect of various combinations of N, P and K on physico-chemical properties of sap

Analysis of Variance

Age 190 days — Temp. 21° C. — 1951–52

Due to	D.F.	Mean sum of squares × 1,000,000				
		Density	Surface tension	Viscosity	Osmotic pressure	Solute concentration
Samples (A)	1	1·114	1·114	1·117	150·000	1·000
Combinations (B) ..	10	170·350*	8753·334*	8948·473*	5968657·000*	468555·800*
Stem parts (C) ..	1	6941·114*	12682·023*	438601·117*	203132084·000*	148·597·000*
B × C	10	23·714	692·323	1566·863*	1291646·600*	175603·000*
Error	21	11·644	330·029	0·542	174·000	5·000
Total	43					

* Significant at 5%

TABLE III

Effect of various combinations of N, P and K on juice characters of sugarcane

N : P : K	Total solids %	Sucrose %	Purity %
15 15 75	22·50	19·98	88·80
75 15 15	17·20	13·87	80·60
60 15 30	23·40	18·80	80·30
30 15 60	23·00	20·74	90·15
15 30 60	20·80	20·52	89·95
30 45 45	22·30	20·18	90·50
45 30 30	22·20	19·78	89·10
60 30 15	17·80	14·59	81·95
30 45 30	21·50	19·99	90·65
15 60 30	23·00	20·90	90·90
30 60 15	22·10	20·00	90·90
15 75 15	19·00	14·28	75·20
S.D. at 5% ..	0·179	0·147	0·579

Physico-Chemical Properties of Sap and Nutrient Ratios.—Density of the sap was highest in the bottom portion of the sugarcane as compared to the top. Amongst the different nutrient ratios $N_{30}P_{30}K_{45}$ showed the highest density while $N_{45}P_{15}K_{45}$ indicated the poorest density (Table V).

Surface tension of the sap was also higher in bottom canes particularly under a ratio of $N_{30}P_{15}K_{60}$. Viscosity of the sap was again high relatively in the bottom portions of the cane and was lowest (1·339) under $N_{45}P_{15}K_{45}$ and highest (1·511) under $N_{30}P_{30}K_{45}$. Highest osmotic pressure was recorded under $N_{30}P_{60}K_{15}$, while the least value was noted under $N_{30}P_{60}K_{15}$. Solute concentration, on the other hand, was high in top canes as compared to the bottom. It also showed wide fluctuations from a value of 1·375 gm./kg. under $N_{15}P_{60}K_{30}$ to a high value of 2·271 gm./kg. under $N_{45}P_{15}K_{45}$ (Table V).

It, therefore, became obvious that treatment with different ratios of N: P: K induced variations in external growth attributes alongside changes in sap characteristics of the sugarcane plant as well (Table V).

Critical Limits of Nitrogen.—These observations conclusively showed the outstanding effect of certain ratios of N: P: K in improving growth and sap characteristics of sugarcane plant inspite of their concentration remaining constant at 105 gm. equivalent per culture. It was made evident that for all growth characters, such as shoot height, leaf and shoot number, optimum

TABLE IV

Effect of various nutrient ratios of growth characteristics of sugarcane plant

N : P : K	Shoot Number 140 days	Shoot Number 190 days	Mean of 2	Leaf Number 140 days	Leaf Number 190 days	Mean of 2
15 15 75	6·0	5·0	5·5	31·0	27·0	29·0
75 15 15	6·0	4·0	5·0	39·0	32·0	35·5
60 15 30	6·0	4·0	5·0	34·0	29·0	31·5
45 15 45	8·0	4·0	6·0	54·0	38·0	46·0
30 15 60	5·0	5·0	5·0	29·0	27·0	28·0
15 30 60	6·0	4·0	5·0	35·0	20·0	27·5
30 30 45	6·0	3·0	4·5	33·0	17·0	25·0
45 30 30	4·0	1·0	2·5	31·0	20·0	25·5
60 30 15	6·0	4·0	5·0	39·0	31·0	35·0
15 45 45	5·0	2·0	3·5	25·0	22·0	23·5
30 45 30	4·0	3·0	3·5	26·0	21·0	23·5
45 45 15	4·0	4·0	4·0	36·0	24·0	30·0
15 60 30	5·0	2·0	3·5	30·0	24·0	27·0
30 60 15	5·0	2·0	3·5	25·0	21·0	23·0
15 75 15	8·0	4·0	6·0	40·0	34·0	37·0
0 0 0	3·0	2·0	2·5	26·0	22·0	24·0
Mean of 16 ..	5·44	3·31		33·31	25·56	

S.D. at 5% for means of 2 = ± 1·900
S.D. at 5% for means of 16 = ± 0·674

S.D. at 5% for means of 2 = ± 7·056
S.D. at 5% for means of 16 = ± 2·505

TABLE IV—(*Continued*)

N : P : K	Stem height (cm.) 140 days	Stem height (cm.) 190 days	Mean of 2	Shoot height (cm.) 140 days	Shoot height (cm.) 190 days	Mean of 2
15 15 75	107·50	123·00	115·25	222·50	252·50	237·50
75 15 15	105·00	150·00	127·50	228·50	290·30	259·40
60 15 30	99·50	135·00	117·25	235·60	270·40	253·00
45 15 45	83·00	120·00	101·50	199·40	270·20	234·80
30 15 60	93·00	142·50	117·75	223·70	288·00	255·85
15 30 60	86·00	155·00	120·50	202·50	276·40	239·45
30 30 45	112·50	157·00	134·75	243·10	285·50	264·30
45 30 30	115·50	152·00	133·75	262·30	300·50	281·40
60 30 15	113·50	154·50	134·00	237·00	304·20	270·60
15 45 45	109·50	147·00	128·25	235·40	273·70	254·55
30 45 45	92·50	130·50	111·50	230·00	287·00	258·50
45 45 15	110·50	152·50	131·50	234·50	298·50	266·50
15 60 30	113·50	148·00	130·75	251·00	277·40	264·20
30 60 15	109·50	120·00	114·75	235·80	266·50	251·15
15 75 15	100·50	132·50	116·50	209·20	258·90	234·05
0 0 0	88·50	125·00	106·75	210·00	261·80	235·90
Mean of 16 ..	102·50	140·28		228·78	278·86	

S.D. at 5% for means of 2 = ± 19·57 S.D. at 5% for means of 2 = ± 25·76.
S.D. at 5% for means of 16 = ± 6·95 S.D. at 5% for means of 16 = ± 9.15

TABLE V

Effect of various combinations of N, P and K on the physico-chemical properties of sap

N : P : K	Top cane	Bottom cane	Mean of 2	Top cane	Bottom cane	Mean of 2	Top cane	Bottom cane	Mean of 2
	Density of Sap			Surface Tension of Sap			Viscosity of Sap		
15 15 75	1·084	1·112	1·098	0·964	0·988	0·976	1·246	1·496	1·371
75 15 15	1·086	1·113	1·099	1·002	1·027	1·014	1·323	1·548	1·435
60 15 30	1·081	1·119	1·095	0·998	1·024	1·011	1·299	1·495	1·397
45 15 45	1·084	1·102	1·093	1·001	1·017	1·009	1·267	1·411	1·339
30 15 60	1·085	1·114	1·100	1·125	1·154	1·140	1·292	1·502	1·395
15 30 60	1·089	1·115	1·102	1·089	1·115	1·102	1·297	1·516	1·407
30 30 45	1·104	1·123	1·114	1·026	1·043	1·035	1·399	1·622	1·511
45 30 30	1·097	1·119	1·108	1·019	1·040	1·029	1·365	1·542	1·453
15 60 30	1·091	1·120	1·106	1·052	1·080	1·066	1·332	1·562	1·447
30 60 15	1·099	1·119	1·109	1·023	1·079	1·051	1·355	1·561	1·458
0 0 0	1·093	1·124	1·108	1·018	1·124	1·071	1·386	1·503	1·444
Mean of 22 ..	1·090	1·115		1·029	1·062		1·323	1·523	

S.D. at 5% for means of—	S.D. at 5% for means of—	S.D. at 5% for means of—
2 = ± 0·0071	2 = ± 0·0374	2 = ± 0·0015
4 = ± 0·0050	4 = ± 0·0264	4 = ± 0·0011
22 = ± 0·0021	22 = ± 0·0113	22 = ± 0·0004

			Osmotic Pressure of Sap			Solute Concentration of Sap		
15	15	75	10·03	15·07	12·55	2·060	1·749	1·905
75	15	15	9·58	15·23	12·40	1·668	1·835	1·752
60	15	30	10·64	15·30	12·97	2·383	1·913	2·148
45	15	45	10·69	13·69	12·19	2·414	2·628	2·271
30	15	60	10·80	16·48	13·64	1·832	2·207	2·019
15	30	60	10·80	13·09	11·95	1·641	1·227	1·434
30	30	45	11·81	16·99	14·40	1·635	1·809	1·722
45	30	30	13·16	16·63	14·89	2·643	1·708	2·176
15	60	30	12·50	17·13	14·81	1·451	1·300	1·375
30	60	15	13·46	16·68	15·07	1·382	1·787	1·584
0	0	0	12·53	16·99	14·76	2·076	1·744	1·910
Mean of 22 ..			11·453	15·750		1·926	1·800	

S.D. at 5% for means of—

2 = ± 0·0270

4 = ± 0·0191

22 = ± 0·0081

S.D. at 5% for means of—

2 = ± 0·0046

4 = ± 0·0033

22 = ± 0·0001

values were recorded when the proportion of nitrogen was 57·14–72·38% of the total nutrition. Below this critical limit, growth of these characters was lowered. As against this, even 14·29% of nitrogen in the total nutrition of the soil appeared to be favourable for sucrose, total solids and purity percentage of cane. Beyond this concentration, nitrogen appeared to be in excess of the normal needs for good juice quality. Density, surface tension and osmotic pressure reached high values under a critical concentration of 28·57% of nitrogen. For high viscosity even lower concentration of 14·29% of nitrogen appeared favourable. For solute concentration, on the other hand, 57·14% of nitrogen in the total nutrition was the best.

On comparison of these responses it became evident that relatively high concentrations of nitrogen of the order of 57·14–73·38% of the total nutrition was necessary for inducing better growth and higher solute concentration. For juice characters, density, surface tension, viscosity and osmotic pressure, even low ranges of the order of 14·29–28·57% appeared favourable. The requirement of nitrogen for this plant, therefore, varied with the characters under consideration (Fig. 1; Table VI).

Critical Limits of P_2O_5.—So far as phosphorus was concerned, increase in the proportion of this ingredient in total nutrition up to certain critical concentration, appeared favourable. Thus for maximum height a concentration of 28·57% P_2O_5 in the total nutrition appeared more favourable than higher ranges. For leaf and shoot number even 14·29% appeared better than the relatively higher ranges of 28·57–57·14%. A tendency to better growth of these characters was noted at 72·38% as well. Total solids and purity coefficients were higher at a critical limit of 28·57%, while sucrose attained highest level at 42·86%. Solute concentration was equally high at lower concentrations of 14·29% P_2O_5 in total nutrition, while surface tension, viscosity and osmotic pressure required a relatively higher percentage (42·86–57·14% P_2O_5) for evincing high values. Here again for growth characters, solute concentration, total solids and purity percentages, phosphorus beyond 28·57% of total nutrition appeared excessive. For sucrose, surface tension, viscosity and osmotic pressure phosphorus beyond 42·86–57·14% of total nutrition appeared to be super-optimal (Fig. 1; Table VI).

Critical Limits of Potassium.—Coming now to potassium, height and leaf number attained maximum values under lower concentrations of 14·28–28·57% K_2O; shoot number was highest when this element constituted 72·38% of total nutrition. It was significant to note that total solids, sucrose and purity percentages also attained high levels when concentrations of K_2O reached 57·14% limit. Although not so useful in higher doses for

height and leaf number, potassium in heavy concentrations appeared most favourable for tillering and juice characters. Potassium was needed in

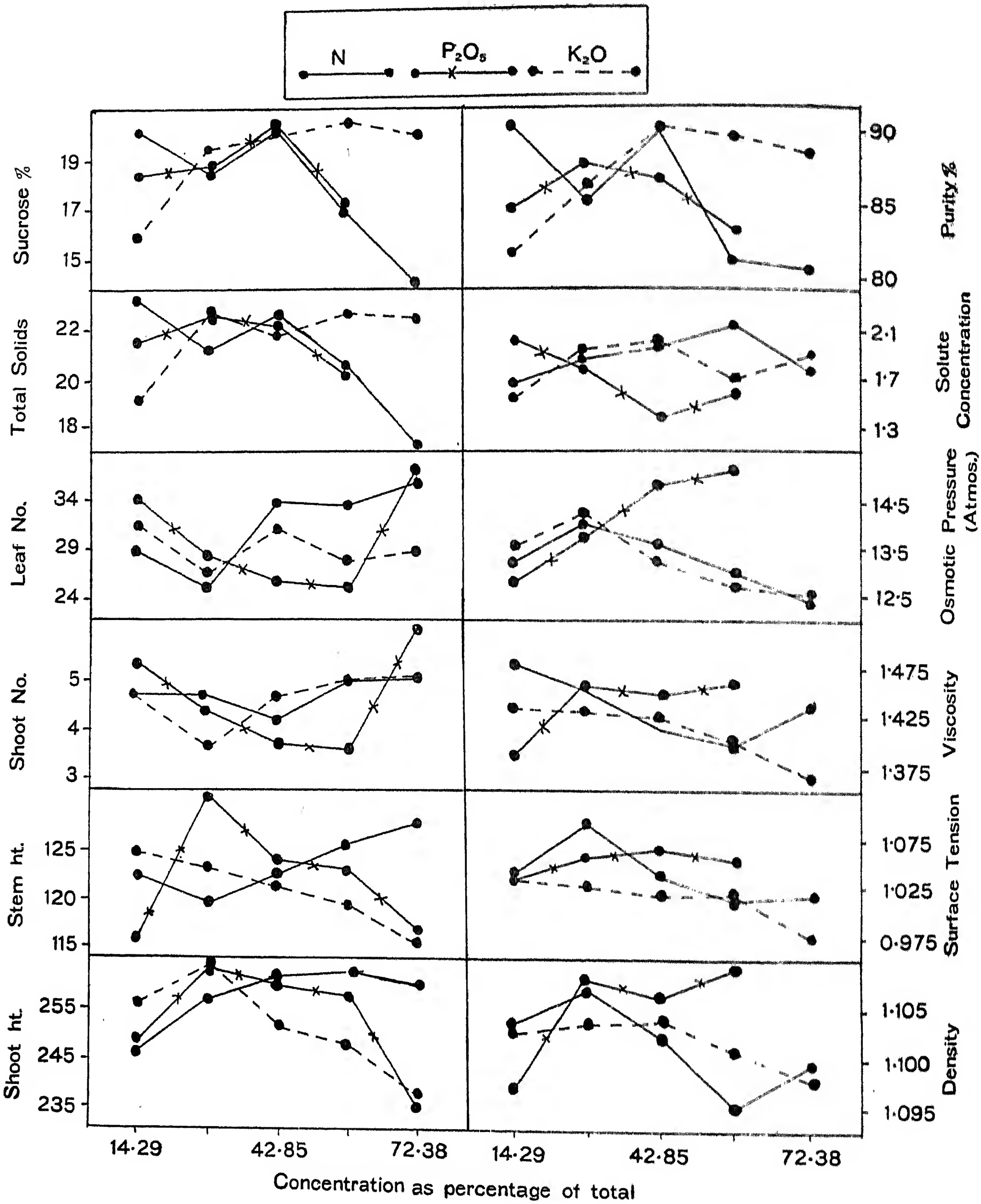

FIG. 1. Growth characters, juice quality and physico-chemical properties of sugarcane in relation to different combinations of N, P_2O_5 and K_2O.

varying quantity for other sap characters. Thus for surface tension a concentration of 57·14% appeared more favourable; for solute concentration and density 42·86% appeared desirable. For high osmotic pressure and viscosity even lower concentrations below 28·57% of total nutrition appeared better (Fig. 1; Table VI).

TABLE VI

Average growth, juice and sap characteristics of sugarcane in relation to the relative concentration of N, P_2O_5 and K_2O in the total nutrition of the medium

	Concentration as percentage of total nutrition				
	14·29	28·57	42·86	57·14	72·38
			Height of shoot in cm.		
Nitrogen ..	245·95	257·95	260·90	261·80	259·40
Phosphorus ..	248·11	263·94	259·85	257·68	234·05
Potassium ..	256·34	264·28	251·22	247·65	237·50
			Cane height in cm.		
Nitrogen ..	122·25	119·69	122·25	125·63	127·50
Phosphorus ..	115·85	130·75	123·75	122·75	116·50
Potassium ..	124·85	123·31	121·50	119·13	115·25
			Shoot number per culture		
Nitrogen ..	4·70	4·70	4·20	5·00	5·00
Phosphorus ..	5·30	4·35	3·67	3·50	6·00
Potassium ..	4·70	3·63	4·80	5·00	5·00
			Leaf number per culture		
Nitrogen ..	28·80	24·90	33·80	33·30	35·50
Phosphorus ..	34·00	28·25	25·67	25·00	37·00
Potassium ..	32·10	26·88	31·50	27·75	29·00
			Total solids percentage in juice		
Nitrogen ..	23·50	21·40	22·60	20·60	17·2
Phosphorus ..	21·53	22·53	22·25	20·55	..
Potassium ..	19·25	22·57	21·90	22·90	22·50
			Sucrose percentage in juice		
Nitrogen ..	20·12	18·40	20·34	16·70	13·87
Phosphorus ..	18·35	18·77	20·45	17·14	..
Potassium ..	15·91	19·53	20·09	20·63	19·98

TABLE VI—*Contd.*

	Concentration as percentage of total nutrition				
	14·29	28·57	42·86	57·14	72·38
			Purity percentage in juice		
Nitrogen ..	90·75	85·28	90·00	81·13	80·60
Phosphorus ..	84·96	87·88	86·93	83·05	..
Potassium ..	82·16	86·77	90·58	90·05	88·80
			Density of sap		
Nitrogen ..	1·103	1·107	1·102	1·095	1·099
Phosphorus ..	1·097	1·108	1·106	1·109	..
Potassium ..	1·103	1·104	1·104	1·101	1·098
			Surface tension of sap		
Nitrogen ..	1·403	1·088	1·035	1·011	1·014
Phosphorus ..	1·030	1·055	1·066	1·051	..
Potassium ..	1·040	1·030	1·022	1·121	0·976
			Viscosity of sap		
Nitrogen ..	1·479	1·453	1·413	1·397	1·435
Phosphorus ..	1·387	1·457	1·447	1·458	..
Potassium ..	1·441	1·436	1·425	1·401	1·371
			Osmotic pressure of sap		
Nitrogen ..	13·19	14·02	13·63	12·97	12·40
Phosphorus ..	12·75	13·75	14·81	15·07	..
Potassium ..	13·61	14·31	13·30	12·80	12·55
			Solute concentration of sap		
Nitrogen ..	1·641	1·871	1·941	2·148	1·752
Phosphorus ..	2·019	1·777	1·375	1·584	..
Potassium ..	1·563	1·969	1·997	1·722	1·905

Taking all these factors into consideration, it appeared, therefore, that all the three ingredients were helpful in certain critical concentrations for various growth and sap characteristics. At the respective optimum level, nitrogen appeared to be better in so far as total solids, purity percentage, viscosity and solute concentration were concerned. Phosphorus, on the other hand, appeared better than nitrogen and potassium, in that, at its respective optimum limit, cane height, shoot and leaf number and osmotic pressure of the sap were improved markedly. Potassium, on the other hand, at its critical

optimum level showed best response on sucrose, density and total height of the plant. There was no fixed sub-optimal or super-optimal limit for the various sap characteristics of sugarcane.

Taking total plant height as the criterion of growth, nitrogen appeared to be required in large percentage (57·14) than phosphorus and potassium. For evincing the best response in leaf number, potassium was required in least quantity. No marked difference in the critical limit for the three ingredients was noted in so far as the tillering was concerned. In contrast to this, potassium was required in higher concentration of 57·14% than either phosphorus (28·57%) or nitrogen (14·29%) for improving juice characters. Comparative studies on barley, paddy and maize showed that nitrogen exhibited sub-optimal effects below 48·4% of the total in barley, below 66·5% in maize and below 53·6% in paddy. Similar critical limits for phosphorus and potassium were 6·3 and 3·3% respectively for all these crops. Critical limit of nitrogen, therefore, did not differ markedly in sugarcane, barley, paddy and maize; those of phosphorus and potassium were undoubtedly higher in sugarcane in comparison to other Graminaceous crops (Lal and Rao, 1954).

Optimum N/P, N/K and P/K Ratios.—The relative proportion in which different ingredients were applied was used to calculate the N/P, N/K and P/K ratios in culture medium. It was significant to note that increase in N/P ratios raised the magnitude of growth markedly; shoot height attained the highest level at N/P ratio of 2:1, cane height and shoot number were higher under N/P ratio of 1:1 and 3:1 respectively. A higher proportion of nitrogen as compared to phosphorus was thus needed for height and shoot number. Similarly N/K ratio of 1:1 appeared more favourable for leaf and shoot number. P/K ratio of 2:1 improved growth in height to a maximum, while a ratio of 5:1 showed the maximum number of leaves and shoots. Data further revealed that except in the case of density, osmotic pressure and viscosity of the sap, where equal nitrogen to phosphorus level in the ratio of 1:1 was needed, in all other cases nitrogen was either needed in lesser or larger amounts for best response. Similarly barring surface tension where nitrogen was needed in smaller quantity than potassium for optimum effects, in all other characters the proportion of N was either equal to or higher than that of potassium. Again with the exception of total solids and solute concentration, where comparatively smaller concentration of P and K was needed to induce best response, in all other direction phosphorus was invariably needed in higher amounts than potassium (Table VII; Fig. 2).

TABLE VII

Effect of various N/P, N/K and P/K ratios on growth and physico-chemical properties of sugarcane

Characters	Ratios					
	0·5	1·0	2·0	3·0	4·0	5·0
N/P						
Shoot height	245·30	256·10	263·23	234·80	253·00	259·40
Cane height	117·63	127·17	125·88	101·50	117·25	127·00
Shoot number	4·25	4·80	5·50	6·00	5·00	5·00
Leaf number	20·25	28·00	31·50	46·00	31·50	35·50
Total solids %	20·90	22·60	20·40	..	23·40	17·20
Sucrose %	17·40	20·35	16·67	..	18·80	13·87
Purity %	82·58	90·10	86·05	..	80·30	80·60
Density	1·10	1·11	1·10	1·09	1·09	1·10
Surface tension	1·10	1·02	1·14	1·10	1·01	1·01
Viscosity	1·41	1·44	1·39	1·34	1·39	1·43
Osmotic pressure	11·95	13·92	13·64	12·19	12·97	12·40
Solute concentration	1·43	1·66	2·02	2·27	2·15	1·75
N/K						
Shoot height	260·23	242·45	252·08	266·50	270·60	259·40
Cane height	124·25	109·83	116·50	131·50	134·00	127·50
Shoot number	4·25	5·33	4·25	4·00	5·00	5·00
Leaf number	27·50	35·50	27·50	30·00	35·00	35·50
Total solids %	22·55	..	21·20	23·00	17·80	17·20
Sucrose %	20·37	..	16·54	20·90	14·59	13·87
Purity %	90·53	..	77·75	90·90	81·95	80·60
Density	1·10	1·09	1·09	1·11	..	1·09
Surface tension	1·09	1·01	1·01	1·06	..	1·01
Viscosity	1·43	1·34	1·39	1·45	..	1·43
Osmotic pressure	14·36	12·19	12·97	14·81	..	12·40
Solute concentration	1·80	2·27	2·15	1·37	..	1·75
P/K						
Shoot height	246·23	265·12	267·40	266·50	251·15	234·05
Cane height	118·88	129·83	132·38	131·50	114·75	116·50
Shoot number	5·00	3·66	4·25	4·00	3·50	6·00
Leaf number	29·50	28·17	31·00	30·00	23·00	37·00
Total solids %	23·10	20·30	19·95	23·00	19·00	..
Sucrose %	19·66	17·88	17·30	20·90	14·28	..
Purity %	85·13	86·78	86·43	90·90	75·20	..
Density	1·10	1·10	1·11	1·10	..	..
Surface tension	1·05	1·02	1·05	1·06	..	..
Viscosity	1·40	1·44	1·49	1·45	..	..
Osmotic pressure	12·45	13·65	15·07	14·81	..	..
Solute concentration	1·79	1·96	1·58	1·37	..	...

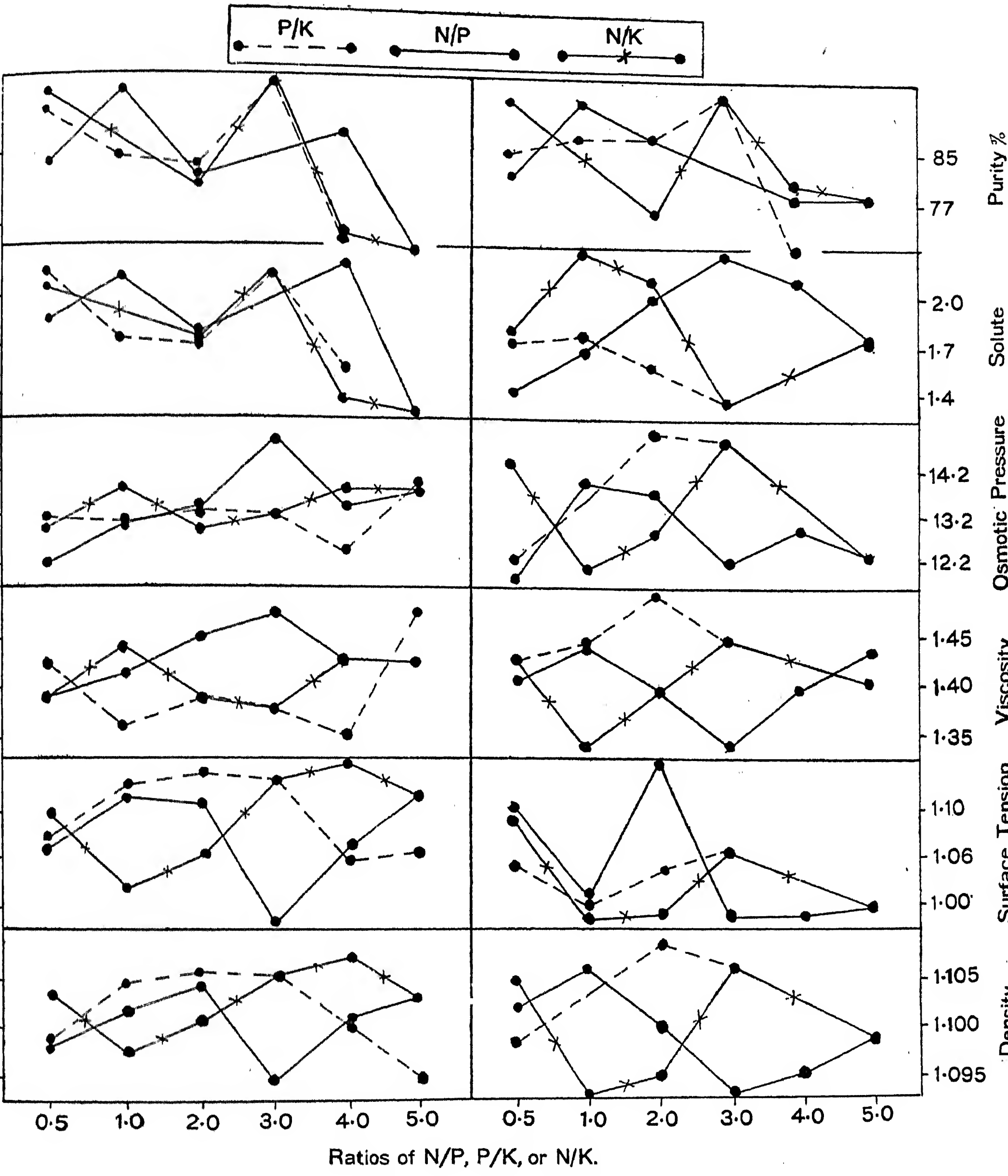

FIG. 2. Growth characters, juice quality and physico-chemical properties of sugarcane in relation to various N/P, N/K and P/K ratios.

For optimum growth of Graminaceous plants like barley, maize and paddy the proportion of nitrogen required was found in earlier investigations to be as high as 4·7–10·2 times that of phosphorus and 18 times that of

potassium. In contrast to these effects, noted earlier by Lal and Rao (1954), the proportion of nitrogen to phosphorus and potassium for optimum growth of sugarcane in present series was never more than 3–4 times. As against this, phosphorus was needed in quantities 2–5 times higher than potassium for the good growth of sugarcane. A proportion of 1·73–2·3 times higher phosphorus than potassium was needed for better development of barley, paddy and maize (Lal and Rao, 1954). Sugarcane thus needed a relatively higher proportion of phosphorus than other Graminaceous plants.

SUMMARY

The effect of 16 ratios of nitrogen, phosphorus and potassium on growth and physico-chemical properties of sugarcane was investigated in local sandy loam soil. All the 16 cultures were identical in one respect, namely, the total concentration of the added nutrient which was maintained at 105 gm. equivalent, while individual nutrient proportion varied over a wide range from a minimum of 15 gm. equivalent to a maximum of 75 gm. equivalent. The following were the outstanding effects:—

Character	Optimum Dose of Nutrients as % of Total Nutrition		
	N	P_2O_5	K_2O
Height of shoot ..	57·14	28·57	28·57
Cane height	72·38	28·57	14·29
Shoot Number.. ..	57·14–72·38	72·38	57·14–72·38
Leaf Number	72·38	72·38	14·29
Average of growth characters	62·28	50·02	28·58
Total solids % ..	14·29	28·57	57·14
Sucrose %	42·86	42·86	57·14
Purity %	14·29	28·57	42·86
Average for juice quality	14·29	33·03	47·63

Characters	Optimum Dose of Nutrients as % of Total Nutrition		
	N	P_2O_5	K_2O
Density	28·57	57·14	28·57–42·86
Surface tension ..	28·57	42·86	57·14
Viscosity	14·29	57·14	14·29
Osmotic pressure ..	28·57	57·14	28·57
Solute concentration ..	57·14	14·29	42·86
Average for physico-chemical properties ..	31·44	40·01	40·01

At its optimum level nitrogen showed marked improvement in total solids, purity, viscosity, solute concentration when compared to other two ingredients. Phosphorus appeared better than nitrogen and potassium and improved height, shoot number, leaf number and osmotic pressure when its concentration was maintained at optimal limit. As against these two, potassium appeared to have a more favourable effect on sucrose, density and shoot height at its optimal level.

Growth of sugarcane also showed some relation with N/P, N/K and P/K ratios in the culture medium. Here again the optimum ratio varied with the character under consideration. The proportion of nitrogen to phosphorus was never more than 3–4 times for optimum growth of sugarcane. Similarly phosphorus was needed in quantities 2–5 times higher than potassium for good growth alone. This proportion, however, differed from various physico-chemical properties. Individual effects of these ratios have been discussed.

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COMPARATIVE EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH AND SAP CHARACTERISTICS OF SUGARCANE

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Introduction

The role of organic manures in maintenance of soil fertility has been recognised for a long time. Occasionally one form of fertilizer and manure appeared better than others. Efficiency of different forms of nitrogenous manures depends largely on the time of their application, climate, season, soil, location and conditions of water-supply. Fertilization with lime, phosphate and potassium, soil organic matter, pH, kind, number and efficiency of micro-organism also regulates to a large extent the efficiency of applied nitrogen. An attempt is made in this paper to present in a connected sequence the relative effects of farm-yard manure, castor cake and sulphate of ammonia on growth and juice characteristics of sugarcane at various levels of its application.

Method and Material

These investigations form part of a comprehensive scheme of researches on physico-chemical properties of sugarcane sap conducted during 1950–54. The experiment cited in these pages was conducted on variety Cos 109, grown on the College Farm under three forms of manure, *e.g.*, sulphate of ammonia, castor cake and farm-yard manure each applied at three levels of nitrogen, *viz.*, 60 and 120 lb. N per acre during the cropping season of 1950–51. The treatments, nine in number, were applied in three randomised blocks with gross and net plot sizes of $36' \times 24'$ and $28' \times 16'$ respectively.

For study of physico-chemical properties, sampling was done at 250 days in the life-cycle. The variation in these directions were analysed in relation to levels of manures, component parts of the shoots and the interaction between treatments and plant parts. The method used for the estimation of these properties has been described earlier (Lal and Tandon, 1953). Correlation coefficients between sap characteristics and yield were also determined.

TABLE I

Effect of varying levels and forms of manures on physico-chemical properties of sap

Analysis of Variance

Temp. 21° Age 250 days 1951–52

Due to	D.F.	Mean sum of squares × 1,000,000		
		Density	Surface tension	Viscosity
Samples (S) ..	1	2·000*	1·317*	4·700*
Treatments (T) ..	7	41·400*	12076·560*	62139·640*
Plant parts (P) ..	2	79·800*	218·888*	14961·500*
S × T ..	7	0·760*	0·283	2·114
S × P ..	2	0·075	0·029	0·213
T × P ..	14	5·800*	138·223*	2119·429*
Error ..	14	0·018	0·260	0·605
Total ..	47			

TABLE I—(*Contd.*)

Due to	D.F.	Mean sum of squares × 1,000,000					
		Osmotic pressure	Solute concentration	D.F.	Moisture %	Bound water %	Free water %
Samples (S) ..	3	2000·000	2·083	..	..	..	..
Treatments (T) ..	7	6425000·000*	590482·100*	7	18127759·430*	47586825·000	47462637·5000
Plant parts (P) ..	2	10047000·000*	135606·063*	2	748066·500	1287400·000	1297050·0000
S×T	21	1000·000	10·174	..	..	..	..
S×P	6	500·000	6·521	..	..	..	..
T×P	14	762000·000*	70894·788*	..	..	..	..
Error	42	1200·000	8·612	14	2113166·430	2453174·286	24740171·429
Total ..	96			23			

* Significant at 5%

TABLE II

Effect of forms and levels of fertilizers on physico-chemical properties of sap

Stem parts	Control	Ammonium sulphate 60 lb.	Ammonium sulphate 120 lb.	F.Y.M. 60 lb.	F.Y.M. 120 lb.	Castor cake 60 lb.	Castor cake 120 lb.	Mean of 16
Density of sap								
Top	1·083	1·084	1·079	1·083	1·084	1·085	1·079	1·083
Middle	1·084	1·082	1·082	1·082	1·086	1·089	1·083	1·085
Bottom	1·083	1·079	1·077	1·076	1·070	1·083	1·081	1·080
Mean of 6 ..	1·083	1·082	1·079	1·080	1·083	1·086	1·081	

S.D. at 5% for means of: 2 = ± 0·000708; 6 = ± 0·000409; 16 = ± 0·0002502.

Stem parts	Control	Ammonium sulphate 60 lb.	Ammonium sulphate 120 lb.	F.Y.M. 60 lb.	F.Y.M. 120 lb.	Castor cake 60 lb.	Castor cake 120 lb.	Mean of 16
Surface tension of sap								
Top	0·897	0·946	0·959	0·928	0·898	0·965	0·851	0·926
Middle	0·867	0·962	0·962	0·962	0·815	0·968	0·885	0·923
Bottom	0·838	0·959	0·958	0·957	0·925	0·963	0·883	0·931
Mean of 6 ..	0·867	0·956	0·960	0·949	0·879	0·965	0·873	

S.D. at 5% for means of: 2 = ± 0·00109; 6 = ± 0·00089; 16 = ±0·00039

Stem parts	Control	Ammonium sulphate 60 lb.	Ammonium sulphate 120 lb.	F.Y.M. 60 lb.	F.Y.M. 120 lb.	Castor cake 60 lb.	Castor cake 120 lb.	Mean of 8
Free water as % of total moisture								
Top	31·55	18·28	18·25	21·08	20·89	2·75	30·04	23·67
Middle	36·20	25·48	24·32	26·55	21·91	17·31	21·53	23·88
Bottom	27·46	30·03	27·75	28·21	20·84	12·00	21·95	23·10
Mean of 3 ..	31·74	24·60	23·44	25·88	20·21	17·35	24·51	

S.D. at 5% for means of; 1 = ± 15·076; 3 = ± 8·705; 8 = ± 5·330.

TABLE II—(*Contd.*)

Bound water as % of total moisture

Top	68·45	81·72	81·65	78·92	79·11	77·24	69·96	76·32
Middle	63·80	74·52	75·68	73·45	78·09	82·69	78·47	76·12
Bottom	72·54	69·97	72·25	71·79	76·16	88·00	78·05	76·53
Mean of 3 ..	68·26	74·74	76·56	74·72	77·79	82·64	75·49	

S.D. at 5% for means of: 1 = ± 14·985; 3 = ± 8·652; 8 = ± 5·298.

Viscosity of sap

								Mean of 16
Top	1·772	1·816	1·700	1·800	1·837	1·988	1·661	1·811
Middle	1·694	1·824	1·735	1·752	1·831	1·995	1·656	1·804
Bottom ..	1·660	1·746	1·691	1·715	1·767	1·933	1·706	1·755
Mean of 6 ..	1·708	1·795	1·709	1·755	1·811	1·972	1·674	

S.D. at 5% for means of: 2 = ± 0·00167; 6 = ± 0·00097; 16 = ± 0·00059.

Osmotic pressure of sap

								Mean of 32
Top	17·51	19·04	19·01	17·86	18·88	19·17	18·33	18·62
Middle	17·33	18·35	19·36	18·14	19·12	19·76	18·89	18·80
Bottom	16·95	17·96	19·28	16·24	17·08	18·29	17·94	17·75
Mean of 12 ..	17·26	18·45	19·22	17·41	18·26	19·07	18·38	

S.D. at 5% for means of: 4 = ± 0·0485; 12 = ± 0·028; 32 = ± 0·01715.

Solute concentration

								Mean of 16
Top	1·888	2·387	2·342	2·160	2·944	2·003	2·567	2·229
Middle	2·099	1·909	2·317	2·065	3·278	1·950	2·413	2·261
Bottom	2·202	2·060	2·227	1·904	2·602	1·911	1·979	2·124
Mean of 6 ..	2·063	2·118	2·295	2·043	2·941	1·955	2·319	

S.D. at 5% for means of: 2 = ± 0·00615; 6 = ± 0·00355; 16 = ± 0·00217.

EXPERIMENTAL RESULTS

Effect of Forms and Levels of Manures on Physico-Chemical Properties of Sugarcane Sap.—Analysis of various factors showed that various fertilizer treatments affected density, surface tension, viscosity, osmotic pressure, solute concentration significantly; bound and free water content did not vary appreciably. Different parts of the sugarcane plant showed the outstanding response on all the physico-chemical properties excepting the bound and free water content. Interaction between the treatment and the stem parts also showed a highly significant effect on density, surface tension, viscosity, osmotic pressure and solute concentration (Table I).

The density of the sugarcane sap varied slightly from 1·079 under 120 lb. sulphate of ammonia to 1·086 under 60 lb. castor cake. Differences between the two extremes were statistically significant. Increase in level of nitrogen from 60 to 120 lb. in case of sulphate of ammonia and castor cake, lowered the density of the sap. Density of the sap increased from top to middle but decreased markedly to the lower value in the bottom stem (Table II; Fig. 1).

High surface tension was recorded under 60 lb. castor cake, while low surface tension was noted in control. Differences in these two were statistically significant. Increase in the level of ammonium sulphate caused a rise in the surface tension of the sap, but similar increase in the dose of farm-yard manure or castor cake lowered this character significantly. Further, bottom canes showed the highest surface tension while top and middle canes indicated medium and low values respectively. Differences between each portion were statistically significant (Table II; Fig. 1).

Viscosity of the sap varied from 1·708 in control to 1·972 under 60 lb. N as castor cake. Increase in the level of sulphate of ammonia or castor cake from 60 to 120 lb. N, reduced the viscosity. In farm-yard manure higher doses, on the contrary, increased viscosity. It was also evident that the top cane showed highest viscosity which gradually became low as lower internodes were taken for sampling. Differences between top, middle and bottom canes were again statistically significant (Table II; Fig. 1).

Osmotic pressure of the sap also varied from a low value of 17·26 atmosphere to a high value of 19·22 atmospheres under 120 lb. N as sulphate of ammonia; farm-yard manure also improved this character at higher N levels. In case of castor cake, however, higher level of 120 lb. N lowered osmotic pressure. Osmotic pressure also gradually increased from top to middle canes but declined subsequently in the bottom canes. The differences were found to be statistically significant (Table II; Fig. 1).

Solute concentration also varied from 2·063 gm. mol. per kg. dry weight in control to a value of 2·941 gm. mol. per kg. dry weight under 120 lb. N as farm-yard manure. Addition of each of the fertilizers at 120 lb. N level, appeared better than lower doses of 0 or 60 lb. Further the top canes showed the highest solute concentration in comparison to middle and bottom canes (Table II; Fig. 1).

Bound water of the tissues also varied from 68·26 to 82·64 per cent. of total moisture. In general, the greater the level of nitrogen applied as sulphate of ammonia or farm-yard manure the higher was the bound water

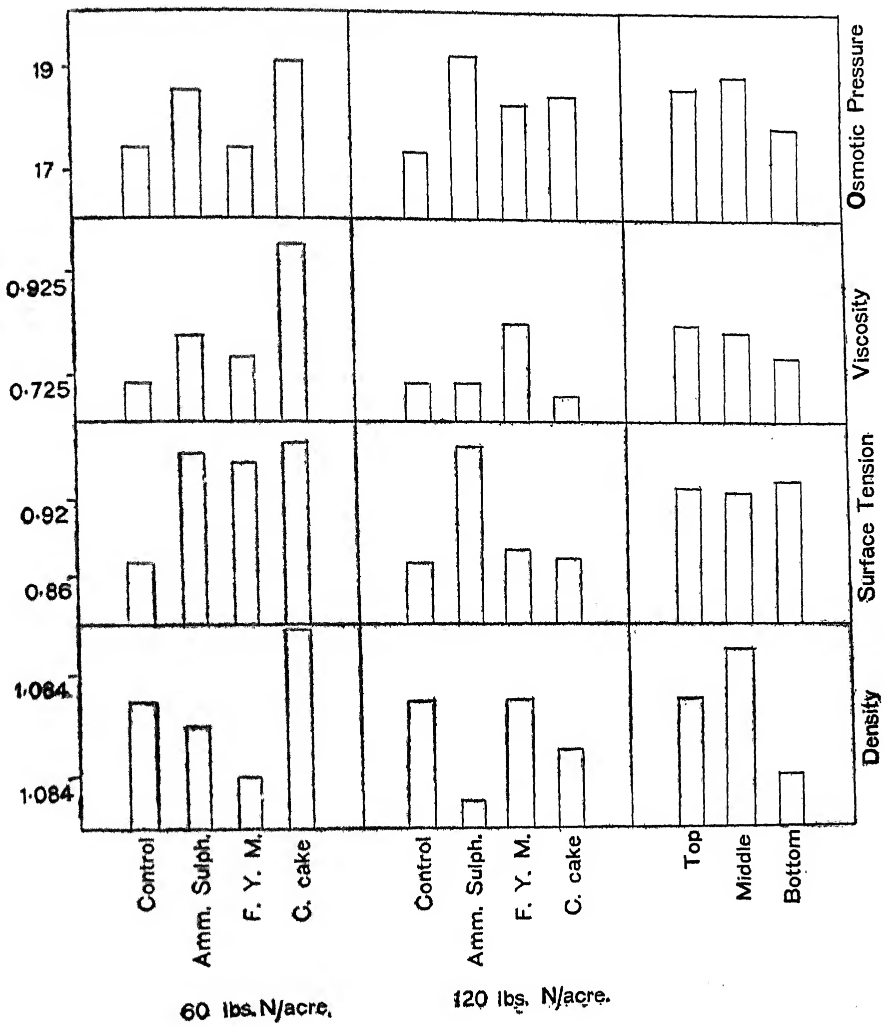

FIG. 1. Physico-chemical properties in relation to levels and forms of nitrogen.

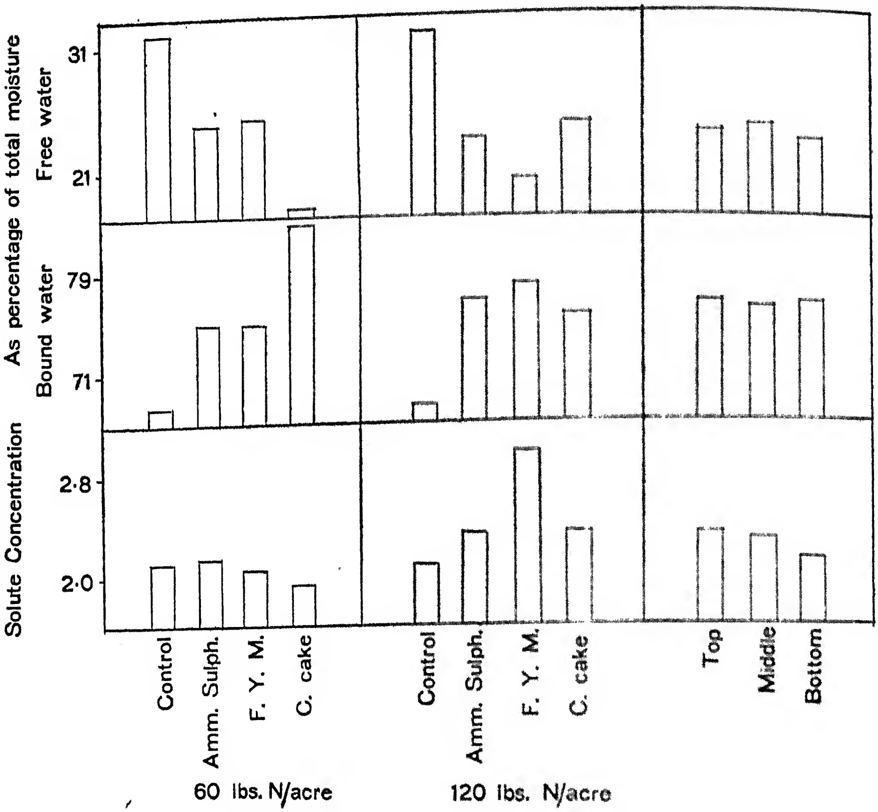

FIG. 1—(*Continued*)

content. In castor cake, however, increases beyond 60 lb. N lowered bound water content. Bound water did not vary significantly in top, middle and bottom canes (Table II; Fig. 1). Free water content expressed as percentage of total water varied in the reverse direction. In none of the treated series, could the free water attain a higher level than the control; the differnces in the free water content of top, middle and bottom canes were also insignificant (Table II; Fig. 1).

DISCUSSION

A critical examination of the data revealed that all physico-chemical properties of the sap excepting bound and free water were markedly influenced by the three forms of manures. As recorded earlier (Lal and Sreenivasan, 1953) levels of nitrogen showed an equally important effect on growth and juice characters. Taking an over-all picture of these responses, sulphate of ammonia at 120 lb. N showed the best effect on height, weight of main stem and osmotic pressure of the sugarcane sap. This fertiliser at this level

also reduced the density of the sap to a minimum. So far as the farm-yard manure was concerned, a 120 lb. N dose appeared best from the view-point of shoot number, purity of juice and solute concentration. Castor cake at 60 lb. N improved density, surface tension and bound water to a maximum. At still higher level of 120 lb. N improvement in leaf area, sucrose, °Brix and purity were recorded. At 60 lb. N, castor cake was poorest in so far as the solute concentration and free water were concerned, while at 120 lb. N, viscosity was also lowered to a minimum (Tables II and III).

TABLE III

*Effect of levels and forms of manures on growth characters of sugarcane**

Levels	F.Y.M.	Castor cake	Sulphate of ammonia	Mean of 72
Height of Main Stem (cm.)				
0 lb. N	169·2	170·0	172·0	170·5
60 lb. N	193·3	200·9	202·4	198·9
120 lb. N	199·5	216·4	217·5	211·3
Mean of 72	187·3	196·9	197·4	
S.D. at 5% for means of: 24 = ± 7·31; 72 = ± 4·20.				
Shoot Number				
0 lb. N	2·87	2·91	2·83	2·87
60 lb. N	4·16	4·12	4·33	4·29
120 lb. N	5·16	4·54	4·45	4·72
Mean of 72	4·15	3·91	3·82	
S.D. at 5% for means of: 24 = ± 0·024; 72 = ± 0·014.				
Area of Leaves				
0 lb. N	1826	2005	2009	1930
60 lb. N	3399	4047	4136	3875
120 lb. N.	4605	5481	3910	4667
Mean of 72	3289	3842	3365	
S.D. at 5% for means of: 24 = ± 524; 72 = ± 301.				
Fresh Weight of Main Stem (gm.)				
0 lb. N	417·1	444·3	436·6	445·1
60 lb. N	496·3	616·4	591·0	567·7
120 lb. N	446·3	665·3	765·5	659·4
Mean of 72	449·3	561·6	584·1	
S.D. at 5% for means of: 24 = ± 17·48; 72 = ± 9·97.				

* Data of Lal and Sreenivasan, 1952.

Levels	F.Y.M.	Castor cake	Sulphate of ammonia	Mean of 18
		Gulcose Percentage of Juice		
0 lb. N	0·7001	0·7821	0·5815	0·6879
60 lb. N	0·5415	0·5633	0·4638	0·5228
120 lb. N	0·4961	0·2691	0·6145	..
Mean of 18	0·5792	0·5217	0·5531	

S.D. at 5% for means of: 6 = ± 0·1614; 18 = ± 0·0932.

		Sucrose Percentage in Cane Juice		
0 lb. N	17·26	17·16	16·69	17·03
60 lb. N	18·15	18·15	17·81	18·03
120 lb. N	17·85	19·10	17·56	18·17
Mean of 18	17·75	18·13	17·35	

S.D. at 5% for means of: 6 = ± 0·928; 18 = ± 0·516.

		°Brix in Cane Juice		
0 lb. N	20·66	20·16	21·16	20·66
60 lb. N	20·50	21·16	21·00	20·88
120 lb. N	20·50	21·16	21·00	20·88
Mean of 18 ..	20·55	20·86	21·05	

S.D. at 5% for means of: 6 = ± 0·5245; 18 = ± 0·3026.

		Purity Percentage of Cane Juice		
0 lb. N	82·66	82·16	81·00	81·94
60 lb. N	86·66	84·66	84·16	85·16
120 lb. N	86·66	89·16	83·00	86·27
Mean of 18	85·33	85·33	82·72	

S.D. at 5% for means of: 6 = ± 3·976; 18 = ± 2·3433.

It was, however, difficult to imagine the extent to which variations in growth were specially related to the changes in the sap characteristics. Certain outstanding relationship may, however, be indicated. Good growth in ammonium sulphate was, for instance, found to be associated with osmotic pressure of the sap; while poorest growth appeared related to low osmotic pressure, in the control. Similarly highest tillering under farm-yard manure

appeared related to high concentration of solutes. The useful effect of 120 lb. N as castor cake on sucrose appeared related to low viscosity of the sap. Castor cake at 60 lb. N improved the bound water markedly. If higher bound water was a criterion of greater drought-resistance of plants (Lal and Mehrotra, 1953) treatment with castor cake at 60 lb. N appeared desirable for including greater colloidal content of tissues.

Sap Characteristics of Top, Middle and Bottom Canes.—Top portions of cane were generally higher in viscosity and solute concentration. High viscosity and high solute concentration were the prerequisites for the efficient functioning of the top region of the sugarcane plant.

TABLE IV

Correlation coefficient between yield of millable canes and other sap characteristics

Characters	Correlation coefficient	S.E.
Yield *vs.* density	0·35	0·42
Yield *vs.* surface tension	0·77	0·186
Yield *vs.* viscosity	0·19	0·43
Yield *vs.* osmotic pressure ..	0·72	0·21
Yield *vs.* solute concentration ..	0·02	0·45
Yield *vs.* bound water	0·51	0·33
Yield *vs.* free water	0·49	0·33

The middle portion of the cane stem showed high density, osmotic pressure and free water content, but was poorest in surface tension and bound water. These portions of the cane stem were connected to the active leafy region at the top and the dry leaf section at the bottom and, therefore, served as a channel of transport for all manufactured materials down to stem. The bottom canes showed highest surface tension and bound water, both of which were favourable for sucrose storage in this region. Further low osmotic pressure and solute concentration in this region indicated the fact that some of the constituents of the cell were not in an osmotically active form and that in the process of their storage, they

were temporarily converted into such forms which contributed to high density of the sap.

Correlation Between Yield and Physico-Chemical Properties.—So far as the sap characteristics were concerned, yield of the millable canes showed a highly significant positive correlation coefficient with surface tension and osmotic pressure of $0 \cdot 77 \pm 0 \cdot 185$ and of $0 \cdot 72 \pm 0 \cdot 21$ respectively. Correlation coefficient between yield and other characters, for instance, density, viscosity, solute concentration and bound and free water were not significant at all (Table IV). It appeared, therefore, that of all the sap characteristics high surface tension and high osmotic pressure showed some intrinsic relation with yield of millable canes.

SUMMARY

Top canes were found to be richer in viscosity and solute concentration. Middle canes were rich in density, osmotic pressure and free water but were poor in surface tension and bound water. Bottom canes showed highest surface tension and bound water but were poorest in density, viscosity, osmotic pressure, solute concentration and free water.

Surface tension and osmotic pressure showed a positive correlation with yield; these indicated that high surface tension and high osmotic pressure were usually associated with high yield of sugarcane. The interrelation between various sap characteristics and yield has been indicated.

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STUDIES ON CARBON SELECTIVITY, FROM SOME ORGANIC COMPOUNDS, AND ITS EFFECT ON GROWTH AND SPORULATION OF *ALTERNARIA TENUIS* STRAIN B CAUSING CORE ROT OF APPLES

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Carbon is essential for all living organisms and it plays an important part in the nutrition of fungi because it forms about 50% of the total dry weight of a fungus. The earlier workers on the physiology of fungi were mainly interested in determining the carbon requirements of various organisms. They concluded that carbon compounds, which could be oxidised and assimilated easily, were the first choice of food for fungi.

Steinberg[27, 28] clearly showed that the fungi reacted differently towards various carbon compounds. The effect of carbohydrates and alcohols on the growth of *Alternaria tenuis* strain B was studied and an attempt was made to determine if the amount of damage to apples was in any way connected with the type of carbohydrate present in the fruit.

Material and Method

After a preliminary study of growth and sporulation of *Alternaria tenuis* strain B on four different media (*viz.*, Asthana and Hawker's medium A, Coon's synthetic medium, Czapeck's medium, Richard's medium) Asthana and Hawker's medium A containing KNO_3; 3·5 gm., KH_2PO_4; 1·75 gm., $MgSO_4$ $7H_2O$; 0·75 gm., dextrose; 5·0 gm. and distilled water 1000 c.c. was selected as the basal medium. Dextrose in the basal medium was replaced by different carbon compounds. Care was taken to provide 2·0 gm. of carbon per litre in each case. This quantity was equivalent to the amount of carbon in 5·0 gm. of dextrose used in the basal medium. As the structural formulæ of polysaccharides are not known their weights were similar to the amount of dextrose present in Asthana and Hawker's medium A. The best pH was found to be 5 and hence all the media were adjusted to that value.

Only pyrex glassware, extra pure chemicals and double distilled water were used throughout this investigation. Liquid cultures containing 50 c.c. of nutrient solution in 150 c. c. conical flasks were sterilized at 10 lb. pressure for 20 minutes and were then inoculated with inoculum of equal size and were incubated for 3 weeks. Four replicates were used in each series. The mycelial mats were filtered, washed with distilled water and dried to constant weight

at 80° C. They were weighed in analytical balance. The following carbon compounds were used:—

A. *Carbohydrates*

1. Monosaccharides
   (*a*) Pentoses: ($C_5H_{10}O_5$)—arabinose, rhamnose, xylose.
   (*b*) Hexoses: ($C_6H_{12}O_6$)—mannose, glucose, galactose.
2. Disaccharides: ($C_{12}H_{22}O_{11}$)—lactose, maltose, sucrose.
3. Trisaccharides: ($C_{18}H_{32}O_{16}$)—raffinose.
4. Polysaccharides: ($C_6H_{10}O_5)_n$—starch, dextrin, inulin.

B. *Glucoside*: ($C_{12}H_{16}O_7$)—arbutin

C. *Alcohols*

(*a*) Trihydric ($C_3H_8O_3$)—glycerine.
(*b*) Tetrahydric ($C_4H_{10}O_4$)—erytheritol.
(*c*) Hexahydric ($C_6H_{14}O_6$)—dulcitol, mannitol, sorbitol.

OBSERVATIONS

The dry weight, nature of sporulation, spore size and septation of spores were carefully studied and the average results are recorded in Table I.

TABLE I

Showing average dry weight in milligrams and sporulation as well as other characters of the spores of A. tenuis *strain B on different carbon compounds*

Carbon compounds	Average dry weight in mg.	Sporulation	Spore size in μ	No. of Transverse septa	No. of Longitudinal septa
Sorbitol	94·2	fair	21·2 × 10·1	1–3	0–2
Glycerine ..	81·7	poor	20·9 × 10·3	1–5	0–2
Erytheritol ..	73·2	poor	20·6 × 10·2	1–4	0–2
Mannitol ..	70·5	poor	21·4 × 9·8	1–6	0–3
Dulcitol ..	65·3	poor	21·0 × 9·8	1–5	0–2
Mannose ..	58·2	good	20·3 × 9·9	1–6	0–2
Dextrin	56·2	absent	..	..	..
Lactose	52·7	good	20·2 × 10·2	1–6	0–2

TABLE I—*Continued*

Carbon compounds	Average dry weight in mg.	Sporulation	Spore size in μ	No. of Transverse septa	No. of Longitudinal septa
Galactose ..	52·6	good	20·8× 9·9	1–4	0–2
Raffinose ..	52·3	fair	19·4×10·1	1–3	0–3
Glucose	46·0	good	20·8×10·3	1–5	0–2
Maltose	44·5	absent	..	..	..
Starch	38·1	absent	..	..	..
Sucrose	36·0	fair	20·3× 9·8	1–5	0–2
Inulin	32·2	absent	..	..	..
Arbutin	29·9	absent	..	..	..
Rhamnose ..	20·1	poor	21·5×10·1	1–4	0–2
Xylose	18·2	good	20·8× 9·9	1–5	0–3
Arabinose ..	16·1	absent	..	..	..
Control (no carbon)	0·0	..	..	..	..

General mean: ∓ C. D. at 1% level=46·9∓ 12·52.

Note.—Poor denotes 1–3 spores per low power field of the microscope, fair sporulation denotes 4–6 spores per microscopic field, good sporulation denotes more than 10 spores per microscopic field.

The results in Table I showed marked variation. Some differences were also observed in different replicates of the same medium. The utility of various carbon compounds was not clear without statistical analysis which was undertaken. The standard error and critical difference were determined.

Analysis of Variance (in mg.)

Sources	D.F.	S.S.	M.S.	F. calc.	Significance
Replicates ..	3	54·83	18·28	·414	No...
Treatments ..	19	42988·20	2262·53	51·23	High
Error ..	57	2517·56	44·16		
Total ..	79	45560·59			

Summary of 21 days dry weight results and conclusions at 1% level of probability.

Replication	..	Non-significant.
Treatments	..	Highly significant.
Standard error	..	3·32
C.D. at 5%	..	9·41
C.D. at 1%	..	12·52

Statistical analysis of results included in Table I indicates that sorbitol, glycerine, erytheritol, mannitol and dulcitol supported significantly better growth of *A. tenuis* strain B. Sorbitol gave significantly best growth amongst the compounds giving good growth. Moderate growth of the fungus was observed on mannose, dextrin, lactose, galactose, raffinose, glucose, maltose, starch and sucrose. Out of the compounds supporting moderate growth starch and sucrose gave significantly less growth than mannose, dextrin, lactose, galactose and raffinose. Significantly poor growth of the fungus was recorded on inulin, arbutin, rhamnose, xylose and arabinose. Among these compounds inulin supported better growth than xylose and arabinose. There was no growth of the fungus in complete absence of carbon in the basal medium.

The dry weights on all the above compounds were also determined after the growth of the fungus for 1 and 2 weeks. It was observed that the general trend of growth on particular carbon compound was similar at different periods. The growth on those carbon compounds which had best dry weight on the 21st day was also similar on 7th and 14th day but maltose showed better growth than all others except sorbitol on 7th day and even on the 14th day the growth was better than on raffinose and glucose. It appears that the utilization of this compound starts earlier but in course of time it slows down. Similarly the growth on lactose was slightly better than on dextrin but this difference was not statistically significant. No autolysis of the mycelium was observed in any series within the experimental period.

The results also indicate that carbon source in the medium influences the amount of sporulation but the spore size is not significantly effected. Good sporulation of *A. tenuis* strain B was noticed on mannose, lactose, galactose, glucose and xylose. It was fair on sorbitol, raffinose and sucrose and poor on glycerine, erytheritol, mannitol, dulcitol and rhamnose. There was no sporulation on dextrin, maltose, starch, inulin, arbutin and arabinose which was also absent on every compound on the 7th day. It was absent on many except on mannose, lactose, glucose and xylose even on the 14th

day. The former two had good while the last two had only fair sporulation at that stage. It is interesting to note that all the hexoses supported good sporulation.

Discussion

Arabinose supported poor growth of *Alternaria tenuis* strain B. Wolf *et al.*[34] also obtained similar results with *Monosporium apiospermum*. Wolf,[33] however, found it useless for *Ustilago zeæ*. Few investigators[5–7, 21] found that it could support good growth. Wolf[33] and Wolf *et al.*[34] had reported that *Ustilago zeæ* and *Monosporium apiospermum* were unable to use carbon in rhamnose. *A. tenuis* strain B differed from them because it could use rhamnose even though it gave poor growth on it. Mehrotra[19] found it to be a moderate source of carbon. Many investigators[4, 5, 7, 17, 21, 33, 34] found that xylose could support good growth of the fungi investigated by them. The present fungus (*A. tenuis*), however, gave poor growth on xylose. Similar result was obtained by Brock[3] for *Morchella esculenta*.

Numerous investigators[1, 2, 5, 10, 13, 19, 24, 27, 29, 33, 34, 36] have reported glucose to be a good source of carbon for the growth of fungi. Weimer and Harter[35] working with *Sphæronema fimbriatum*, Tochinai[32] with *Fusarium lini* and Schade[25] with *Leptomitus lacteus*, however, found them incapable of utilizing glucose. *A. tenuis* strain B gave moderate growth on glucose. Many workers[5, 6, 22, 29, 34] found galactose to be a good source of carbon for the fungi investigated by them. Brock,[3] Horr[10] and Kinsel,[22] however, found that it supported poor growth of *Morchella esculenta*, *Aspergillus niger*, *Penicillium glaucum* and *Diplodia zeæ*. The present fungus gave moderate growth on it. Mannose supported moderate growth of *A. tenuis* strain B. Steinberg[27] also reported similar results, even though some other investigators[5, 6, 22, 34] had obtained good growth of their fungi on mannose. Ezekiel *et al.*,[4] Horr[10] and Mehrotra[19] reported it to be a poor source of carbon for the growth of *Phymatotrichum omnivorum*, *Aspergillus niger*, *Penicillium glaucum* and for some species of Phytophthora.

The disaccharides (lactose, sucrose and maltose) are known to influence the growth of various fungi in different manner. La Fuze,[12] Mosher *et al.*[22] and Steinberg[27] found that lactose was useless for fungi investigated by them. Blank and Talley,[1] Fergus[5] and Wolf[33] found it to be a good source of carbon. A number of workers[1, 3, 4, 19, 23] reported maltose to be a good source while Fergus[5] as well as Schade[25] found it to be a poor source of carbon. Tochinai[32] reported sucrose to be a poor source while Blank and Talley,[1] Fergus,[5] Leonian,[13] Schade,[25] Wolf,[33] Weimer and Harter[35] and Young and Bennett[36]

found it to be a good source of carbon for the fungi investigated by them. All of them, however, gave only moderate growth of *A. tenuis* strain B.

Mehrotra[19] as well as Saksena and Mehrotra[24] found that raffinose was a poor source of carbon. Srivastava[26] and Wolf[33] recorded good growth on it. *A. tenuis* strain B. differed from them and supported moderate growth only.

Starch has been reported to be a good source of carbon.[3, 19, 26, 31] The present fungus gave only moderate growth on it. Wolf[33] reported that *Ustilago zeæ* was unable to grow on it while Fergus[5] obtained poor growth of *Penicillium digitatum.* The results obtained with dextrin were similar to those reported by Patel *et al.*,[23] Wolf[33] and Wolf *et al.*[34] as it supported only moderate growth. Fergus[5] and Mehrotra,[19] however, found it to be a poor source for a number of fungi examined by them. Mehrotra[19] as well as Saksena and Mehrotra[24] found that inulin supported moderate to good growth of their fungi but *A. tenuis* strain B gave poor growth and in this respect it resembled *Morchella esculenta* and *Penicillium digitatum* investigated by Brock[3] and Fergus.[5]

The present investigation clearly indicates that dulcitol, glycerine, erytheritol, mannitol and sorbitol give significantly better growth of *A. tenuis* strain B. Each of the above carbon compound is known to give good growth of some fungi and moderate or poor growth of others. Dulcitol is reported by Wolf *et al.*[36] to be a good source for *Monosporium apiospermum*, Mehrotra[19] as well as Saksena and Mehrotra[24] found it to be unsatisfactory for some species of Phytophthora and Pythium. According to the same investigators, erytheritol, mannitol and sorbitol were also unsatisfactory but Blank and Talley[1] and Patel *et al.*[23] obtained good growth of *Phymatotrichum omnivorum* and *Pestalotia psidii* respectively on mannitol. Hawker[8] also reported it to be a poor source of carbon.

SPORULATION

The source of carbon in the basal medium influences sporulation. Hawker[8] has reported that production of perithecia of *Melanospora destruens* is influenced by the kind and concentration of sugar used. *Alternaria tenuis* strain B produced abundant sporulation on xylose, glucose, galactose, mannose and lactose. Similarly Mix[20] reported that glucose, mannose, and lactose were favourable sources for the formation of pycnia of *Phyllosticta solitaria*. Mathur *et al.*[18] also found that xylose, glucose and galactose were good and mannose a poor source for the sporulation of *Colletotrichum lindemuthianum*. According to Timnick *et al.*[30] glucose and lactose are good for sporulation of *Diaporthe phaseolorum* var. *batatatis*. Timnick *et al.*[31]

found glucose and galactose to be good for *Melanconium fuligenium*. Hawker and Chaudhuri[9] have reported that lactose is a poor source of carbon for the reproduction of *Pyronema confluens*.

Leonian[11] reported that raffinose was a favourable source of carbon for reproduction of Phytophthora. Fair sporulation of *A. tenuis* strain B was also observed on it. Some investigators[15, 17, 20, 23] reported sucrose to be good for sporulation of many fungi. It, however, induced only fair sporulation of *A. tenuis* strain B.

Glycerine, erytheritol, mannitol and dulcitol induced poor sporulation of the fungus under study. Mathur *et al.*[18] also obtained similar results with mannitol. Hawker[8] also observed poor sporulation of *Melanospora destruens* on mannitol. On the contrary Patel *et al.*[23] and Timnick *et al.*[30] found that mannitol induced abundant sporulation of *Pestalotia psidii* and *Diaporthe phaseolorum* var. *batatatis* respectively.

In the present investigation there was no sporulation of *A. tenuis* strain B on maltose, dextrin, starch, inulin and arbutin. Though Lilly and Barnett,[15] Mathur *et al.*[18] as well as Timnick *et al.*[30, 31] reported that maltose induced good sporulation of some fungi. Patel *et al.*,[23] however, obtained only poor sporulation on it. Timnick *et al.*[30] reported that the sporulation of *Diaporthe phaseolorum* var. *batatatis* was good on starch, poor on sucrose and it was completely absent on sorbitol.

Alcohols (dulcitol, glycerine, erytheritol and mannitol) gave significantly best growth of the fungus but induced poor sporulation. Mannose, galactose, glucose and lactose supported moderate growth but they induced good sporulation. Xylose gave significantly poor growth but the sporulation was good. While arabinose and arbutin which supported poor growth checked sporulation also. It is thus quite evident that there is no correlation between growth and sporulation.

The present investigation also established that each organism must be individually investigated for determining the best source of carbon for its growth or reproduction.

SUMMARY

Alternaria tenuis strain B was grown on Asthana and Hawker's medium A as well as on 19 different compounds of carbon. Sorbitol, glycerine, erytheritol, mannitol and dulcitol gave significantly good growth. Moderate growth was recorded on glucose, galactose, mannose, maltose, lactose, sucrose, raffinose, dextrin and starch. The growth was significantly poor on xylose, rhamnose, arabinose, inulin and arbutin. There was no growth without carbon.

Best sporulation of the fungus was noticed on xylose, glucose, galactose, mannose and lactose. The sporulation was fair on sucrose, raffinose and sorbitol. It was poor on glycerine, erytheritol, mannitol and dulcitol. Spore formation was completely checked on arabinose, maltose, starch, dextrin, inulin and arbutin. In general the sporulation was good on all the disaccharides and the growth was best on sorbitol. It was also observed that there was no correlation between growth and sporulation.

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